Corrected sagittal tomography of the temporomandibular joint

Influence of errors in film and patient positioning on linear and angular measurements

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Panmekiate S, Petersson A, Rohlin M, Åkerman S, Isberg P-E. Corrected sagittal tomography of the temporomandibular joint. Influence of errors in film and patient positioning on linear and angular measurements. Acta Odontol Scand 1995;53:264–269. Oslo. ISSN 0001-6357.

The aim of this study was to assess the variation in film and patient positioning in horizontally corrected sagittal tomography of the temporomandibular joint (TMJ). The influence of this variation on linear and angular measurements of some anatomic structures of the TMJ was also studied. There was no significant variation in film positioning in the tomograph, using a multi-film cassette. The variation in positioning the patient in the tomograph was significant when four dental assistants were asked to place the Frankfort plane parallel to the horizontal plane. The measurements with the film in a straight position were compared with the measurements with the film angulated, to simulate the mean variation in film and patient positioning. Linear and angular measurements of anatomic structures were performed in arthrotomograms of 58 joints, representing joints with superior disk position and joints with anterior disk position with and without reduction. There was a difference between the two measurements for four different distances and one angle independent of diagnosis. No differences could be found between patients belonging to the different diagnostic groups. The results indicate that variation in patient positioning influences linear and angular measurements of anatomic structures in TMJ arthrotomograms. □ *Diagnostic imaging; radiography, diagnostic; temporomandibular joint diseases*

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Tomography yields more accurate diagnostic information than plain film techniques for the examination of the temporomandibular joint (TMJ) (1–6). To determine the spatial relationships between the mandibular and temporal components, linear and areal measurements have been performed on TMJ tomograms in several investigations (7–15). Linear and angular measurements of anatomic structures in arthrotomograms have also been made to study the location of the insertion of the disk attachment of the upper joint compartment and the angulation and the prominence of the posterior slope of the articular eminence in relation to the TMJ disk position (16, 17). The resulting measurements indicated that there was a difference between individuals with superior disk position and those with anterior disk position with and without reduction with regard to the location of the insertion of the upper border of the posterior attachment of the disk. Even though statistically significant, the differences were small. The results focused our interest on whether variations of the tomographic procedure may cause greater differences than the innate difference in the anatomic structures between individuals. Thus, the aims of this study were to assess the variation in film and patient positioning in horizontally corrected sagittal tomography of the TMJ and to determine whether the variation will influence the linear and angular measurements of some anatomic structures of the TMJ.

Materials and methods

Arthrotomography of the TMJ

The contrast examination was performed as a single-contrast dual-space arthrography (17). Tomography was performed with a Polytome U (Massiot/Philips, Paris, France), using a tomographic angle of 48° without a grid. The X-ray tube was Siemens Bi 125/30/50 R with a target size of $0.6 \times 0.6\ mm^2$ and 2-mm total Al filtration. Collimation included a circular collimator with a diameter of 1.5 cm, resulting in a field size diameter of 6.5 cm at the film plane. A multi-film cassette containing four pairs of rare-earth screens and four films was fixed in the cassette holder of the tomograph and exposed (18).

The TMJ examination was initiated with a mentovertical view of the TMJ in accordance with Lysholm & Wickbom (19). In the radiograph a base line was drawn between the image of lead balls placed in the external auditory canals. Lines were drawn through the medial and lateral poles of the condyles and extended until they intersected the base line. The laterally open angle between this line and the base line was measured with a protractor to the nearest 5°. These measurements were used for the orientation of the patient in the tomograph (2). A cephalostat was used to position the patient in a standardized manner during the tomography (20). The patient's head was fixed with ear

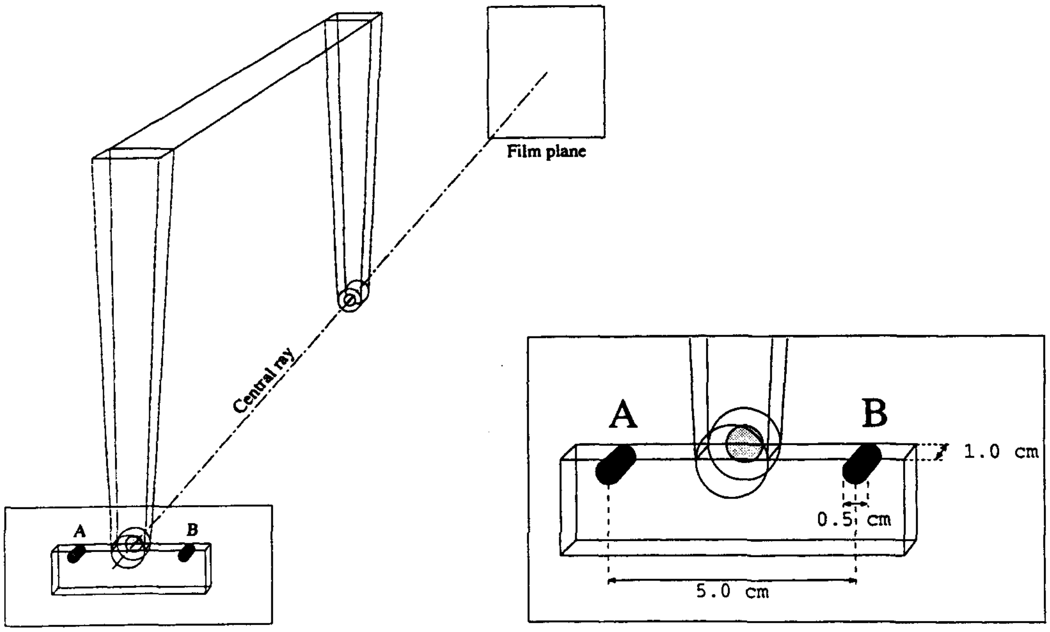

Fig. 1. Device to assess the variation in film positioning. Straight metal rods *A* and *B* with a length of 1.0 cm and a diameter of 0.5 cm were positioned 5.0 cm apart at the upper surface of an acrylic plate. The long axes of the wires were perpendicular to the film plane.

rods and a forehead support and oriented with the Frankfort plane (plane connecting the lower margin of the orbit with the upper margins of the external auditory meatus) horizontal. The cephalostat was rotatable 360° with markings for every fifth degree, and it was rotated in accordance with the individual condylar angles. In this manner the tomographic sections were perpendicular to the long axis of the condyle in the horizontal plane.

Assessment of variation in film positioning

Two straight metal rods with a length of 1.0 cm and a diameter of 0.5 cm were positioned 5.0 cm apart and parallel to each other in a square acrylic plate (Fig. 1). Rods A and B in Fig. 1 were positioned at the upper surface of the plate, and the plate was fixed at the ear rod of the cephalostat closest to the X-ray tube with the upper surface horizontal and the rods perpendicular to the film plane. The plate was adjusted so as to be within the tomographic plane. Two multi-film cassettes, each containing four films, were exposed by one examiner.

In the resulting 20 tomograms a line connecting the upper borders of the images of the 2 metal rods was drawn. Parallel to this line another line intersecting the upper edge of the film was drawn. The angle between the latter line and the upper edge of the film was measured. From these measurements of the radiographs the mean and standard deviations of the variation in film positioning were calculated. Two-way analysis of variance was used to calculate the variation in film positioning between the two cassettes and between the four films in the cassettes.

Assessment of variation in patient positioning

Four dental assistants who regularly perform TMJ tomography were asked to position 10 patients so that the Frankfort plane was parallel to the horizontal plane. After the first assistant had placed the patient in the described position, one of the authors measured the angle between the reference and the horizontal planes. The angle was measured with the aid of a horizontal pointer and a semi-circular protractor. The pointer indicated the lower margin of the orbit. The origin of the coordinates of the protractor was fixed at the upper surface of the ear rod of the cephalostat (Fig. 2). The angle between the horizontal plane of a water level and the protractor was measured. The patient was removed from the cephalostat. After a short while another assistant was asked to place the same patient in the cephalostat and a new measurement was made, until the 4 assistants had each positioned 10 patients. The mean and standard deviation of the variation in patient positioning were calculated from the 40 measurements. Two-way analysis of variance was used to calculate the variation in patient positioning between the four assistants.

Deviation in linear and angular measurements in TMJ arthrograms caused by variation in film and patient positioning

Arthrotomograms in the open mouth position of 58

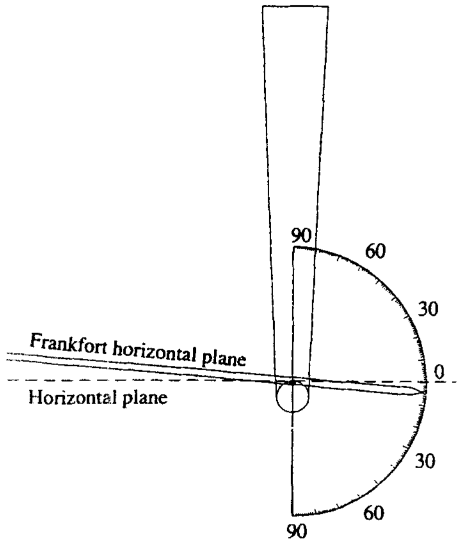

Fig. 2. Device to assess the variation in patient positioning. A semicircular protractor at the ear rod for measuring the angle between the Frankfort plane and the horizontal plane was used. The origin of the coordinates of the protractor was fixed at the upper surface of the ear rod of the cephalostat.

of 60 joints examined in previous studies (16, 17) were used in the present study. Of four or five tomograms of each joint, one tomogram was randomly selected from the lateral, central, or medial part of the joint. The 58 joints represented 3 diagnostic groups: 20 joints with superior disk position, 18 with anterior disk position with reduction, and 20 joints with anterior disk position without reduction.

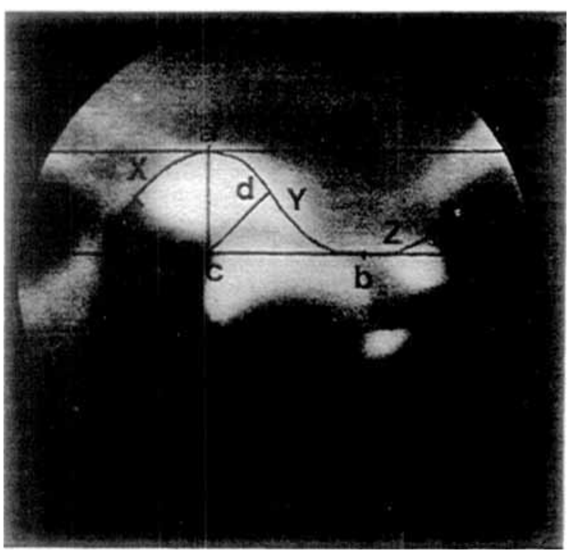

Fig. 3. A drawing superimposed on an arthrotomogram of the temporomandibular joint, showing the measured distances *X*, *Y*, and *Z*. The distance cd represents the prominence of the posterior slope of the articular eminence. Angle abc indicates the angulation of the posterior slope of the articular eminence.

Table 1. Variation in patient positioning for 4 dental assistants placing 10 patients in the cephalostat of the tomograph. The variation was expressed as the angle (degree) between a reference plane of the patient (Frankfort plane) and the horizontal plane. Figures without sign denote backward rotation and figures with a minus sign denote forward rotation of the head around the ear rods

	Dental assistant			
Patient	A	B	C	D
1	1	4	5	2
2	1	3	2	8
3	2	5	5	5
4	−3	1	−2	−3
5	−1	1	−3	−3
6	1	0	2	5
7	2	2	2	4
8	3	4	3	6
9	2	5	5	6
10	3	5	2	9

The first linear and angular measurements were performed as described in detail in previous studies (16, 17), with the upper edge of the film as a reference line (Fig. 3). When the second measurements had been performed, the mean angle of the variation in film positioning was added to the mean angle of the variation in patient positioning. A line was drawn to intersect the upper edge of the film at an angle corresponding to the combined mean angle of variation. This line was used as a new reference line, and all measurements were repeated.

The linear and angular measurements with the reference line parallel to (first measurement) and angulated from (second measurement) the upper edge of the film were compared between the three diagnostic groups and within each diagnostic group by two-way analysis of variance with repeated measurements on one factor.

Results

The variation in film positioning in the two cassettes showed a mean value of 0.4°, with a standard deviation of 0.89°. No difference was found between either cassettes or the order of the films in the cassette ($p > 0.05$).

The variation in patient positioning in the cephalostat, expressed as the angle between the Frankfort plane and the horizontal plane, is presented for the four dental assistants in Table 1. The mean value was 2.5°, with a standard deviation of 2.9°. One of the operators varied more in her patient positioning than the other three operators (range, −3° to 9°). The variation in patient positioning between the operators was significant ($p < 0.01$).

Table 2. Differences in linear and angular measurements with the reference line parallel to the upper border of the film (first measurement) and measurements with the reference line angulated to the upper border of the film (second measurement). The angulation was made to simulate the variation in film and patient positioning in temporomandibular joint arthrotomography. Three diagnostic groups were included: superior disk position ($n = 20$), anterior disk position with reduction ($n = 18$), and anterior disk position without reduction ($n = 20$)

Variable		Level of significance in the two-way analysis of variance: Between first and second measurements	Between diagnostic groups	Interaction between diagnostic groups and the repeated measurements
Distance (mm)	X	***	NS	*
	Y	***	NS	NS
	Z	*	NS	NS
	$X+Y+Z$	NS	NS	*
	cd	***	NS	NS
Angle (degree)	abc	***	NS	NS

*** $p < 0.001$; * $p < 0.05$; NS, $p > 0.05$.

Table 3. Mean and standard deviation (SD) of the first (distance $X1$ and angle abc1) and the second (distance $X2$ and angle abc2) measurements. Three diagnostic groups were included: superior disk position ($n = 20$), anterior disk position with reduction ($n = 18$), and anterior disk position without reduction ($n = 20$)

Variable		Superior disk position		Anterior disk position with reduction		Anterior disk position without reduction	
		Mean	SD	Mean	SD	Mean	SD
Distance (mm)	$X1$	6.4	3.3	7.9	2.4	6.2	5.1
	$X2$	7.0	3.1	8.2	2.5	6.4	5.1
Angle (degree)	abc1	36.2	4.3	38.5	5.1	37.2	6.0
	abc2	35.6	4.6	37.7	5.3	35.7	6.4

Table 2 presents the analysis of variance for the difference in linear and angular measurements with the reference line parallel to (first measurement) and angulated from (second measurement) the upper edge of the film. There were differences between the first and second measurements of the distance X, Y, Z, cd, and the angle abc. No differences were found between the three diagnostic groups. Interaction between the diagnostic groups and the repeated measurements could be found for the distances X and $X + Y + Z$. The standard deviations of all measured distances and the angle were high, as presented in Table 3 for distance X and for angle abc.

Discussion

Different sources of error may influence the accuracy and precision of measurements in TMJ radiography. The total measurement error is the combined effect of errors due to the projection of the object onto the film, anatomic landmark identification and registration, and the measurement procedures. The error of the presented measurement procedure in TMJ tomography accounted for a small part of the total variation. One observer performed all measurements, to avoid errors in the tracing and measurement procedures caused by inter-observer variation. In accordance with the results of other studies on linear measurements in TMJ tomograms (12, 21), we have previously found the precision to be high (16, 17). The measurement precision for angular measurements was also high (16).

The error caused by film positioning was of no significance in the present study even though we utilized two different multi-film cassettes with four films in each cassette. To standardize the patient positioning during tomography, a cephalostat is built into the tomograph at our clinic and used for all tomographic procedures in which the patient can be seated. With the aid of the cephalostat—that is, the ear-plugs and forehead support—the variation in patient positioning is intended to be minimized. The projection errors in cephalometry have been shown to be less than 1% for length measurements and less than $\pm 1°$ for angle measurements when the object was rotated in the sagittal and frontal planes less than $\pm 5°$ from the proper position (22, 23). Variation in patient positioning in the cephalostat can arise in the transverse, sagittal, and frontal planes. In the present study the variation caused by rotation around the transverse axis was investigated, because variations in the other two planes were supposed to be smaller.

The greatest source of error was found to be the inter-operator variation in patient positioning. There was also a wide variation within one of the operators, indicating difficulties in placing the patients in a reproducible orientation in accordance with the Frankfort plane. The patient variation significantly influenced the measurements of most distances and the angle used to compare the three diagnostic groups. This was because the film edge was chosen as the reference line, a procedure also applied by Dumas et al. (10) and Ichikawa et al. (24). In other previous TMJ studies, a line connecting anatomic landmarks—for example, the squamotympanic fissure and the crest of the articular eminence—has been utilized as the reference line (5, 7–9, 12, 15, 21). The advantage of such a reference line is that the measurements are not affected by variation in film and patient positioning on repeated tomography (21). The disadvantage of the application of a reference line solely on the basis of anatomic landmarks might be the biologic variation of the landmarks (25). The biologic variation of TMJ anatomy is shown in the present study by the wide standard deviation of the mean of the measured variables within one and the same diagnostic group. The results of measurements performed in histologic sections of TMJ autopsy specimens also indicated a wide biologic variation (26). It can be questioned whether the squamotympanic fissure is a valid point as a landmark, since it is not always clearly depicted by tomography and is present only in the central and medial parts of the TMJ. From a diagnostic point of view the anatomic structures of the TMJ in the lateromedial direction are of interest because anterior disk position is more frequently observed in the lateral part than in the central and medial parts of the TMJ (27–30). The selection of a reference line in the radiographs, whether outside or within the TMJ, has to be considered in accordance with the variables of interest. The question is whether such care can be given to patient positioning in the cephalostat that random errors can be decreased to an extent enabling the utilization of the film edge as a reference line and comparison between different patients. For a selected number of patients in prospective studies it might be worth considering using a device indicating the true horizontal line like a light-cross or the instrument used for error measurements of this study. However, for routine examinations making retrospective studies possible, this is too time-consuming.

In studies of variables with wide biologic variation and large methodologic errors, it might be relevant to reduce the influence of the variance by increasing the number of cases. Such an effect is confirmed by the results of the present study compared with the results of the two previous studies that were based on identical measurements and similar material (16, 17). In the present study there was no significant difference in the measured distances representing the location of the insertion of the disk attachment of the upper joint compartment between the categories of disk position. However, in one of our previous studies based on three times more radiographs, differences were found for some of the measured distances, indicating differences in the insertion of the disk attachment between the three diagnostic groups (17).

In conclusion, we have shown that variation in patient positioning influences linear and angular measurements in TMJ arthrotomography. In any study using linear or angular measurements to compare groups of patients, error analysis should be undertaken to enable the results to be interpreted in the light of the magnitude of the errors. For the observed difference to be considered real, it must exceed the error by a margin. It has been recommended that the observed difference should be at least twice the standard deviation of the estimating error before the difference is considered clinically relevant. The clinical significance should be the salient point for the interpretation of the results, irrespective of whether the statistical difference is small or large.

Acknowledgements.—Grants were received from the Faculty of Odontology, Lund University, Sweden.

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Received for publication 19 September 1994
Accepted 2 December 1994

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